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ABSTRACT

More than half of the high school students in the United States are in general and vocational programs. Students who complete vocational programs, however, score significantly lower on science achievement tests than do students in the academic curriculum nationwide. As work in business and industry becomes more technologically based, the differences between vocational and academic learning must be drastically reduced. The Southern Regional Education Board (SREB)-State Vocational Educaton Consortium's goals to raise significantly the basic competencies--mathematics, science, and communications--of students pursuing vocational studies at the secondary level must be achieved. This document discusses: (1) those goals; (2) strategies for raising science achievement; (3) the current science achievement of vocational completers using data from the 1988 National Assessment of Educational Progress tests in science, mathematics, and reading; (4) current conditions of science education for vocational completers; and (5) the challenges that face vocational and academic teachers. (KR)

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Linking Vocational and Academic Education

SREB-State Vocational Education Consortium

IMPROVING SCIENCE EDUCATION FOR VOCATIONAL COMPLETERS

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SREB-State Vocational Education Consortium

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The Goal

More than half of the high school students in America are in general and vocational programs. Students who complete vocational programs, however, score significantly lower on science achievement tests than do students in the academic curriculum nationwide. As work in business and industry becomes more technologically based, the differences between vocational and academic learning must be drastically reduced. How well vocational students perform in high school and later will determine, in good measure, how well America performs in an increasingly global economy.

It is not only appropriate, but absolutely essential, that the SREB-State Vocational Education Consortium's goal to raise significantly the basic competencies--mathematics, science, and communications--of students pursuing vocational studies at the secondary level be achieved. In science the goal is to close, by one-third, the gap between the achievement scores of vocational students and the scores of 1986 students nationwide who indicated they were in an academic curriculum. This is not an unrealistic goal, for vocational students have shown that they can achieve more than is now expected of them.

All high school students must be able to interpret successfully what they read, solve work-related science and mathematics problems, and make clear-cut decisions. The current practice of teaching higher level science to some students and lower level science to others means that far too many students are not able to accomplish these tasks. The Consortium strives to use different ways of teaching to challenge and help more students achieve higher level science competencies. Those in the Consortium effort must stress differences in the way students learn science, not differences in what students learn.

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Strategies for Raising Science Achievement

Consortium leaders have found that integrating higher level science concepts and vocational studies provides an opportunity to change the way that students in vocational or general programs learn science. The following strategies have been designed to effect that change for those students.

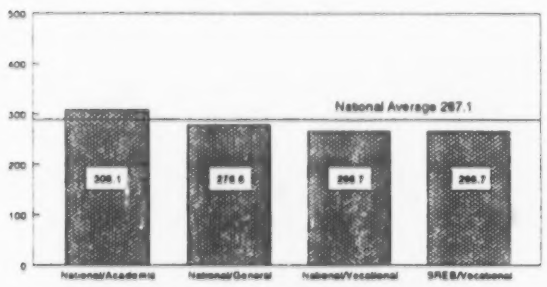
- Establishing higher expectations in science;
- Revising vocational programs to reinforce more effectively scientific concepts;
- Revising science courses to teach essential scientific concepts in greater depth and through an applied process;
- Requiring vocational majors to complete a coherent sequence of three science courses taught in greater depth than now taught;
- Encouraging vocational and academic teachers to work together in preparing students for continuing learning on the job or in school;
- Providing guidance and counseling services that help students plan and pursue a more rigorous program of vocational and science studies; and
- Providing a system of extra help enabling students to complete successfully a program of vocational studies that includes higher level scientific content.

Current Science Achievement of Vocational Completers

In 1988 the National Assessment of Educational Progress tests in science, mathematics, and reading were administered at the SREB-State Vocational Education Consortium pilot sites to students who were completing a program that included at least four credits in a vocational major. These students performed as well in science as vocational students nationally, but significantly below the national average for students in the general curriculum (see Figure 1). However, in mathematics these same students were significantly above the national average for general students and were at the national average in reading. The vocational students at pilot sites with access to lab-based science courses performed as well or higher than general students nationally. **Currently, vocational students are better prepared in mathematics than they are in science.**

FIGURE 1

Average Science Scores,
by Type of High School Curriculum

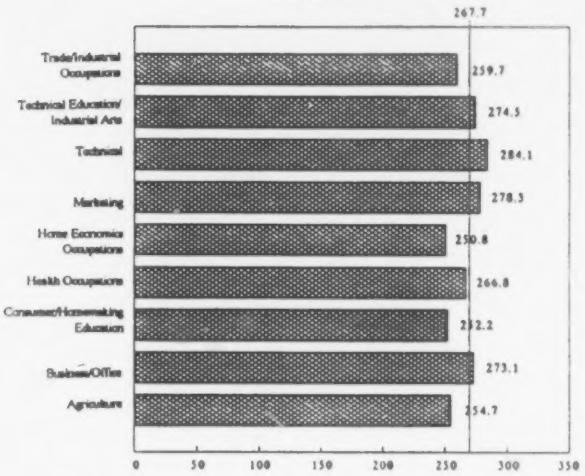


SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at pilot sites who had completed four or more courses in a vocational major.

A wide variance also exists in the science achievement of students from different vocational majors (see Figure 2). Students in agriculture and home economics had the lowest scores, while students from business and technically oriented programs had scores above the regional average. In general, students in business and technical courses take more college preparatory lab-based science courses than do students from other vocational fields.

FIGURE 2

Average Science Scores,
by Type of Vocational Program
as Reported by Students



NOTE: 267.7 represents SREB/Vocational score.

SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at pilot sites who had completed four or more courses in a vocational major.

Achievement in the various sciences reflects the type of science courses taken in high school. For example, students completing vocational programs did better in the earth and life sciences than in physics and chemistry (see Table 1). In general, they average about ten percent fewer correct responses in each content area--life science, physics, chemistry, earth and space science, and nature of science--than did academic students nationally.

TABLE 1

Average Percent of Students Indicating Correct Response,
by Science Content Areas

Science Content Areas	SREB Completers	Nation/Academic
Life Sciences (28 Questions)	50%	60%
Physics (7 Questions)	47	58
Chemistry (8 Questions)	38	49
Earth & Space Science (10 Questions)	51	59
History of Science (1 question)	27	33
Nature of Science (15 Questions)	49	58

SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at a pilot site who had completed four or more courses in a vocational major.

Fewer vocational students than academic students seem to realize how science can help them in their daily life. For instance, according to the NAEP test results, considerably fewer vocational students report using science to make personal decisions regarding health or to solve contemporary problems. Outside of school, more vocational students than academic students, however, are involved in activities that are heavily based on scientific principles. For example, more vocational students report that they have grown gardens and have repaired mechanical things. These practical experiences provide an excellent and untapped basis for teaching lab-based biology, chemistry, and physics (see Table 2). Selecting and organizing essential scientific content in a way that guides

TABLE 2

Vocational and Academic Students' Perceptions of Science

	Vocational Students	Academic Students
Use science to:		
Select foods	42	50
Stay healthy	60	73
Decide to smoke or not	50	62
Science has MUCH potential to:		
Prevent starvation	32	44
Prevent energy shortages	57	76
Cure diseases	67	87
Prevent birth defects	47	60
Save natural resources	51	55
Prevent water pollution	54	61
Science experiences outside of school:		
Read science books/articles	35	46
Grow a garden	45	33
Fix mechanical things	59	48
Visit science museums	28	35
Talk about science with friends	19	28
Care for an animal	75	75

SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at a pilot site who had completed four or more courses in a vocational major.

teaching and anchors it to the world that students recognize and seek to understand will help students see the importance of science in their lives.

Current Conditions of Science Education for Vocational Completers

Low Expectation For Science

Students who recently completed vocational programs believe that science and vocational teachers are expecting too little of them. Forty-five percent of the 3,100 high school seniors at the pilot sites who took the 1988 National Assessment of Educational Progress test in science said that if they could repeat high school, they would study more; 35 percent said they would pursue a more rigorous program in mathematics and science.

Twenty-six percent of the students said they never had any homework assignments during high school. This ranged from four percent at one site to 55 percent at another site. Interviews with over 300 seniors completing a vocational major reveal that they averaged less than two hours of homework each week. (In contrast, students pursuing both a vocational major and a college preparatory program of study said they spent approximately 10 hours a week on homework.) More than one-half the students interviewed said that academic teachers expect too little from them.

The following baseline information from the 1988 National Assessment data suggests that teachers have low expectations:

- 14 percent of the vocational students said they were denied enrollment to higher level mathematics and science courses;
- 75 percent reported that they did not take a science course during their senior year of high school; 59 percent did not take a mathematics course;
- 55 percent reported that they were not encouraged to take higher level mathematics or science courses; and
- 59 percent of the students said the content in their courses was highly repetitive.

Many teachers do not believe these students can master the essential concepts taught in the lab science courses provided to college preparatory students. This view is best expressed by a pilot site teacher who responded to the question, "Do students pursuing vocational studies spend time in the science lab?" He said, "No! I don't allow vocational students into my science lab because they would destroy the equipment." The teacher was then asked, "You mean those students who repair your car at the vocational center?" After a long pause he said, "I need to do some rethinking."

A review of information given to eighth and ninth grade students in pilot sites schools clearly suggests a two-tiered high school science curriculum. Students planning to pursue college are required to complete three lab-based science courses--biology, chemistry, and physics. However, other youth, who will handle hazardous waste, use and repair highly technological tools and equipment, produce and use chemicals, work in medical labs, and perform patient care functions, are required to complete only two low-level science courses--courses that are inadequate for preparing them for either employment or postsecondary education. Students pursuing a vocational major need a solid foundation in science to understand the basis for certain practices in their vocational field and for continued learning on the job or in formal education programs.

It is evident that in most schools the content depth in the science sequence for students in the general and the vocational curriculum is shallow. In many sites, the second science course for vocational students pursuing trade and technical studies is earth science or environmental science, which are unrelated to their vocational studies. **Science and vocational teachers have never concurrently asked the question, "What is a proper science sequence for preparing today's general and vocational students for employment and further education?"**

TABLE 3

Course Selection Assistance Received
by Students Completing Vocational Programs

• Encouraged choice of math or science courses:	
No one	51%
Counselor	21%
Parents	16%
Vocational teachers	2%
Non-vocational teachers	10%
• Assistance in planning four-year program of study:	
Parents met with school personnel	15%
Counselor	48%
No one	52%
• Time vocational teachers spent working with counselor or students on educational plans:	
None	37%
Less than 2 hours annually	35%
Over 10 hours	11%

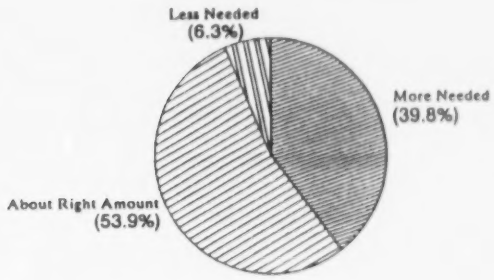
SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at a pilot site who had completed four or more courses in a vocational major.

Little Assistance for Science Course Selection

Students pursuing vocational studies receive little assistance or encouragement from either teachers or counselors in the choice of mathematics and science courses (see Table 3). In fact, 51 percent of students report that no one advised them. Twenty percent report they received assistance from the school counselor; ten percent received help from a non-vocational teacher; and only two percent received any help from a vocational teacher. **One year after high school, however, 39 percent of students who had completed a vocational program said more emphasis was needed in their instructional programs on the scientific**

FIGURE 3

Perceptions of SREB Vocational Completers About the Level of Emphasis Placed on Showing the Use of Scientific Principles In Their Vocational Programs (N=1,361)



SOURCE: Results of SREB follow-up one year after high school graduation of 1988 SREB pilot site students who had completed four or more courses in a vocational major.

principles underlying their vocational field of study (see Figure 3).

Vocational Students Take Too Little Science and What They Take Is Too Shallow

The courses students choose in high school are far more important in advancing their achievement in science than the number of credits they gain. Low level science courses are not usually lab-based and are limited in content. This includes physical or general science, general or basic biology, and general or basic chemistry. Students who do not advance beyond these courses will be severely limited in their understanding of science. An analysis of transcripts at the pilot sites reveals that students who have completed four or more credits in a vocational major had an average of 2.2 science credits, with approximately one credit earned in non-lab based physical or general science, and approximately one credit in a biological science that is mostly non-lab based. Sixteen percent took chemistry, and only about one percent, physics. Nevertheless, lab-based biology and physics represent the scientific foundation for many vocational fields. These same students averaged 2.7 math credits, with only 1.6 credits being earned in Algebra I or higher level courses (see Table 4).

TABLE 4

Average Amount and Type of Mathematics and Science Credits

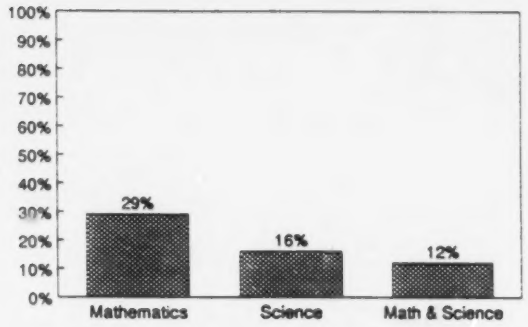
Mathematics	
2.7	Total Math Credits
1.6	Credits: Algebra I or higher
61%	Completed Algebra I
33%	Completed Geometry
Science	
2.2	Total Science Credits
1.0	Credit: general, physical, or earth science
0.9	Credits: Biological Science
16%	Completed Chemistrty
1%	Completed Physics

SOURCE: Analysis of transcripts of courses taken by SREB pilot site seniors who had completed four or more credits in a vocational major.

Only 12 percent of the students met the Consortium's goal of completing three mathematics and three science credits, with two credits in each field being equivalent to content taught in college preparatory courses (see Figure 4). This ranges from zero percent at some sites to over 55 percent at one site. The more a given high school differentiated the mathematics and science content into various levels of courses, the lower was the percentage of students who met the Consortium's goal. Only 16 percent of the students completed three science credits, with at least two credits in college preparatory lab science courses; 29 percent, however, completed three mathematics credits, with at least two credits earned in Algebra I or higher level courses. The Consortium's assumption is that the integration of science and vocational education studies will increase students' motivation for learning science. More students would complete higher level

FIGURE 4

Percent of 1988 Vocational Completers
With Four or More Courses in a Vocational Major
Who Fulfilled SREB Consortium Course Requirements



SOURCE: Analysis of transcripts of courses taken by 1988 SREB pilot site seniors who had completed four or more credits in a vocational major.

science courses if it were expected of them and they could see the need for it.

Little Emphasis on Reinforcing Science by Vocational Teachers

The potential of the vocational curriculum for reinforcing underlying scientific concepts is inadequately developed. For example, only 26.6 percent of vocational students said their vocational teachers often stress science; yet, 56.6 percent said their teachers often stress mathematics (see Table 5). Only in health occupations courses did 50 percent of the students say their teachers often stress science.

Students' perceptions that vocational teachers give little emphasis to reinforcing underlying scientific concepts is consistent with the views expressed by teachers of its importance. Only 30 percent of 500 vocational teachers indicated in a survey that it is extremely important for them to improve and reinforce scientific skills in their teaching; yet, in the same survey, 60 percent say it is extremely important for them to stress mathematics. Only one vocational teacher in five said that he or she is well prepared to reinforce scientific concepts in a vocational context. This contrasts with one in three in mathematics. Most vocational teachers said they spent little or no time each week reinforcing and enriching students' scientific skills, as contrasted to only five percent who made the same statement about mathematics. At present, vocational teachers do not see that stressing science is as important as stressing mathematics.

However, there are exceptions. Some vocational teachers place great stress on teaching scientific concepts. These teachers recognize the importance of helping students grasp a broader understanding of why and how things work. They believe this better prepares students to cope with the

TABLE 5

Percent of Students Indicating the Extent to which Vocational Teachers Stressed the Importance of Reading, Mathematics, and Science Skills, and Corresponding Average Scores

	Reading		Mathematics		Science	
	Percent of Students	Score	Percent of Students	Score	Percent of Students	Score
Often stressed	46.6%	54.8	56.2%	296.1	26.6%	270.9
Never stressed/could not recall being stressed	23.8%	51.7	17.1%	287.1	42.2%	264.6

NOTE: Percentages will not add up to 100% because other answer choices were available.

SOURCE: Results from National Assessment of Educational Progress Science test administered in 1988 to students at a pilot site who had completed four or more courses in a vocational major.

changing nature of problems likely to be encountered in a work setting. These teachers often have administrators who support and encourage them to obtain the preparation and materials necessary for integrating science into their instruction.

Little Emphasis on Teaching Science Through an Applied Process

A survey of pilot site personnel indicated that fewer than one-third of the science teachers believe it is important to relate scientific concepts to students' vocational pursuits. Furthermore, fewer than one in six said they are well prepared to do it. Interviews of seniors pursuing a vocational major at pilot sites revealed that most could not recall specific learning examples in either their vocational or science classes where knowledge of science was used to solve or understand a problem in their vocational field of study. However, they could provide numerous examples from their vocational classes when asked a similar question about mathematics. In essence, what we now have is a shallow treatment of too much material that gives students no real understanding of anything.

Based on observations of science courses that enroll large numbers of general and vocational students, science instruction for these students is textbook-centered, with the main focus on memorizing scientific terms and facts. Few students report having frequent lab experiences as part of their science courses. Too often science instruction is unrelated to students' life experiences and vocational interests. However, science teachers from several sites have found that vocational students can be motivated to master key concepts from physics and chemistry if they are taught through an applied instructional process that links the use of science to solving work-related and real life problems. General and vocational students can master a core of essential scientific concepts if provided in-depth instruction that includes allowing them to apply their knowledge in a context that is meaningful to them. This greater infusion of applied techniques in teaching high school sciences may even improve college bound students' understanding of scientific principles which are so often taught only in their abstract form.

Science teachers in some schools, in cooperation with vocational teachers, are implementing new applied courses for teaching higher level science content. Although limited, science teachers in some sites are revising regular college preparatory lab science courses to teach only essential concepts and are doing so through a functional and applied process. During the 1989-90 school year, more than 9,000 students in 355 high schools in 7 SREB states were enrolled in an applied physics course. **The keys for teaching higher level science content through a more functional approach are having a supportive principal, appropriate instructional materials and staff development, and opportunities for science teachers to plan and interact with vocational teachers.**

Science and Vocational Teachers Seldom Meet Together

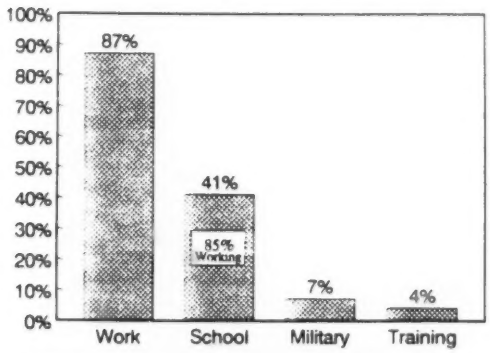
Throughout the ages technology has been based upon and has developed from scientific principles; and, the field of science has been greatly advanced by technology, which has provided the tools, motivation, and direction for expanding scientific theory. Since vocational education is based upon the application of technology in the various fields, it is clear that vocational studies and the sciences are dependent upon one another. From the pilot site teacher survey, however, we know that most science and vocational teachers never meet together to plan instructional activities. In fact, 77 percent of the science teachers said they never meet with vocational teachers; while 49 percent of vocational teachers said they never meet with science teachers.

Students Who Complete Vocational Programs Continue Their Education

Most secondary schools operate on the assumption that vocational students will not continue their learning after high school. This is no longer true, if it ever was. Vocational students who complete four or more credits in a vocational major engage in a wide range of activities one year after leaving high school. Most continue their learning in either a work or institutional setting. For example, 41 percent of those surveyed at the pilot sites were continuing their education in a variety of postsecondary institutions and 87 percent of them also were working either full- or part-time (see Figure 5).

FIGURE 5

Activities One Year After Graduation
for Students Completing Four Credits in a Vocational Major



SOURCE: Results of SREB follow-up one year after high school graduation of 1988 SREB-pilot site students who had completed four or more courses in a vocational major.

The Challenges

The major challenge for vocational and academic teachers today is to raise significantly the scientific knowledge and skills of students pursuing a vocational major. No longer can science or vocational teachers ignore the need to provide these students with a solid grounding in scientific concepts. Together they can meet the challenge. The challenge for schools, then, is to develop and implement a plan for changing the current conditions.

Raise Expectations for Science Learning

The first challenge is to recognize that scientific principles provide the common language for workers to express their understanding of what is occurring in a workplace that now is based more on the

manipulation of symbols than on physical objects. Science and vocational teachers need to involve representatives from postsecondary institutions and business and industry to increase the awareness of teachers, counselors, parents, and students to the changing nature of work that now requires individuals to understand scientific concepts on which modern technology functions. For students to see the need for increased studies in science, teachers must arrange learning experiences that allow students to see examples of how science knowledge guides the practices in their chosen fields of vocational study.

To raise expectations, science and vocational teachers must form a partnership to encourage students to take higher level science courses that deepen their understanding of their vocational field. Together those teachers can take immediate steps to close down access to low level science courses that do nothing to prepare students for either advancement in the workplace or continued learning in postsecondary institutions. Also, they can assist the counselor in revising the literature given to parents and students in the eighth, ninth, and tenth grades. Revised literature should set forth a sequence of at least three science courses designed to prepare students for continued learning. Finally, these teachers can encourage students pursuing vocational studies to take a third science course during their junior or senior year of high school. By joining forces, science and vocational teachers will find--some for the first time--that these students can learn more rigorous science content. At the same time, they will be conveying that confidence to their students.

Science and vocational teachers also can raise expectations for students by working together to devise non-traditional types of homework assignments in science. A major emphasis should be on applying learning activities to vocational studies, as opposed to memorizing meaningless information and facts. This approach provides a different way for students to learn, and one that will enable them to see the need for increased understanding of science.

Teaching Essential Scientific Content in Greater Depth

Improving the achievement in science of vocational students requires increasing the amount and quality of science instruction received by these students. The challenge facing science departments is to place less emphasis on differentiating science content for these students and more emphasis on differentiating instructional methods and on deepening knowledge. Students pursuing vocational studies do not need two or three watered-down, low level survey of science courses. They need to master a core of essential concepts from lab-based biology, chemistry, and physics, taught in a manner that helps them better understand broad vocational fields of study and the utility of science for solving real problems in their fields. This will require that academic and vocational teachers work together to implement new applied academic courses, such as applied biology, chemistry, and physics, or to revise existing biology, chemistry, and physics to teach the most essential concepts through an intensive applied learning process.

One approach for developing a more effective secondary science curriculum for vocational students would be to adapt the applied biology, chemistry, and principles of technology courses developed by the Center for Occupational Research and Development as the basis for designing a three-course science sequence. The advantages for doing this are several. First, science and vocational teachers and leaders across the nation participated in identifying the basic competencies to be addressed through these materials and in developing and field testing instructional modules. Second, instructional modules have been developed to link the teaching of essential scientific concepts with their application in various vocational fields. Third, it will be easier for sites to delete or add established materials than for them to develop their own materials. Fourth, the nature of the applied materials makes it possible for sites to arrange materials into a new sequence of science studies. Fifth, these materials are well suited for vocational teachers in reinforcing many of the scientific concepts as an integral parts of vocational instruction. The challenge is to mold these materials into a coherent lab-based sequence of three science courses for vocational students who are not taking the college preparatory sequence.

Another approach would involve biology, chemistry, and physics teachers at each site in determining the basic 6 to 8 concepts that students should understand in each of the three areas. Science and vocational teachers should then meet to develop courses around those concepts. Either approach would enable general and vocational students to acquire depth of study on core concepts that have greatest utility for the modern workplace.

Stressing Science in Vocational Courses

To improve the achievement in science of vocational students will require that vocational teachers place more instructional emphasis on science. The challenge is for vocational and science teachers to work together to revise the curriculum so that related scientific principles are reinforced as an integral part of vocational instruction. The first step is to relate concepts from principles of technology, applied biology, and chemistry to the school's vocational offerings. The next step is to develop a plan for integrating them into vocational instruction. The intent is not for the vocational teacher to repeat what the science teacher has done, but to devise learning experiences in the vocational lab that require students to use the understanding of science to solve problems and to perform tasks. With the help of science teachers, vocational teachers can adapt existing materials for use in the existing curriculum. Vocational teachers will need science teachers' knowledge base in developing a program to reinforce related scientific concepts in vocational instruction.

Increasing Cooperation Between Science and Vocational Teachers

Little will happen to improve science achievement for general and vocational students unless science and vocational teachers find sufficient time to plan and work together. For science and vocational teachers to change the science achievement of students, they must change their attitudes about the abilities and needs of students pursuing vocational studies. More vocational teachers must see the need for reinforcing related science knowledge in vocational instruction and more science teachers must see the need for teaching science in an applied and functional way.

Science and vocational teachers must believe that vocational students need a better understanding of science and that they are, in fact, capable of much higher achievement if science is taught in a manner that enables them to see the utility of science in terms of their personal goals. To accomplish this requires that science and vocational teachers take the time to learn from each other. One cannot expect students to see the connections between science and vocational study unless the teacher sees them first. The challenge, then, is to teach each other.

Conclusion

Making the above changes will certainly alter the conditions in which vocational and general students learn science. It will require, however, a dramatic departure from the current instructional situation marked by separation between science and vocational teachers. Joining these two instructional groups to work together to integrate science and vocational areas of study is the critical challenge, but the results will "turn on" students to learning and will produce high school graduates who are better able to understand and participate in their world.

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